Pollution Terms of Trade and the Composition of Manufacturing

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Abstract: (241 words)

The trade and environment literature identifies two primary factors that alter the pollution intensity (emissions per dollar) of trade. The *Pollution Haven Effect* (PHE) states that richer countries, which impose stricter environmental regulations, will have a comparative advantage in clean goods. Poor countries will have a comparative advantage in dirty goods and become havens for dirty industries. The *Factor Endowment Hypothesis* (FEH) posits that capital-abundant countries will have the comparative advantage in dirty goods since capital-intensive industries are also pollution intensive. Both hypotheses suggest that exposure to world markets will alter the composition of production so that the pollution intensity of its exports is inversely correlated to the pollution intensity of its imports. To test this, I construct Antweiler's (1996) Pollution Terms of Trade (PTT) index (the ratio of export pollution intensity to import pollution intensity). If the PTT is greater than one, then a country's exports are, on average, dirtier than its imports. I run a panel regression for 57 countries looking at the pattern of pollution intensities in exports, imports, and their PTT. Results support the *FEH* but offer little support for the *PHE*.

Key words: Pollution Haven Effect; Factor Endowment Hypothesis; Pollution Intensity; Composition of Trade

JEL Classification: **F18 - Trade and Environment**

Q56 - Environmental Economics - Environment and Development; Environment and Trade; Sustainability; Environmental Accounting

1 Introduction:

The *Pollution Haven Hypothesis* (PHH) states that production of dirty industries, due to trade liberalization, will migrate from jurisdictions with stringent environmental standards to those with slacker standards (Ederington 2007). Differences in environmental standards can arise from differences in income with richer countries enforcing stricter rules. Differences in standards can also arise from the damage attributed to pollution or the ability of countries to mitigate damage. This can come about from the capacity of the local environment to absorb pollutants or differences in populations exposed to pollutants. The PHH rests on the premise that international trade allows countries to separate consumption of goods from their production. Jurisdictions with stricter environmental regulations can "offshore" dirty production while enjoying the benefits of consumption by importing dirty goods. Typically, the PHH is interpreted as rich countries moving towards cleaner production while poor countries are compelled to produce dirty goods.

Evidence supporting the PHH is hard to find; there is little evidence that dirty industries choose locations based solely on environmental regulations (see for example Antweiler et al 2001). Generally, the cost of complying with environmental rules is small relative to other factors (for example see Jaffe at al 1995).

The *Pollution Haven Effect* (PHE), encapsulated by Taylor (2004), is a weaker hypothesis that finds more support. It states that stricter environmental regulations will deter exports and/or stimulate imports of dirty goods (p 4). The PHE allows for the location of production to reflect other factors so that countries with stricter environmental regulations could still export dirty goods. However, once accounting for all factors that determine production, richer countries would tend to export cleaner goods.

Taylor (2004) makes a compelling argument that one must also account for differences in capital-labour ratios in addition to environmental stringency. The *Factor Endowment Hypothesis* (FEH) states that, countries with higher capital-labour ratios will have a comparative advantage in capital-intensive industries. To the extent that capital-intensive production is also pollution intensive, we would expect capital-abundant countries to have a comparative advantage in pollution-intensive industries. Since per capita income and capital-abundance tend to go hand in hand, failure to account for capital stocks may lead one to attribute to environmental stringency what is properly attributed to growth in capital.

Although the theory is clear about the location of pollution intensive production, and hence the trade in dirty goods, existing data provides some interesting puzzles. Khan (2003) and Ederington et al (2004) show that, for the United States, the composition of manufactured and exports have both moved towards a "cleaner" mix of industries. The puzzle is that imports have also shifted towards a cleaner mix of goods. They find that the pollution intensity of manufacturing production, imports, and exports, after accounting for changes in the techniques of production, has decreased for most pollutants. Khan further shows that the composition of imports is getting cleaner faster than exports. Both claim that US data fails to support either the PHH or the PHE.

In this paper, I follow Khan (2003) and Ederington et al (2004), and look at the composition of imports and exports in terms of a country's pollution intensity of traded goods. I look at a broad selection of countries, both developed and developing, rather than just look at the US. To account for that fact that the pollution intensity of imports and exports may be moving in the same direction, I use Antweiler's *Pollution Terms of Trade* (PTT) This is constructed as the ratio of the pollution intensity of exports divided by the pollution intensity of imports. The basis for the PTT follows the logic of the *Factor Content Theorem*. The factor content theorem states that, for example, capital-abundant countries will be a "net-exporter" of capital, as embodied in their goods exports, and a "net-importer" of factors that are locally scarce. The corollary is that countries can "export" more pollution than they "import" through trade in goods. If secular changes are taking place that are driving the composition of both exports and imports to cleaner industries, and as long as the composition of exports is getting cleaner faster, then the PTT will fall. The empirical question I pursue is whether countries with higher incomes, all things equal, have a lower PTT.

Note that the Factor Content Theorem assumes countries use identical technologies. As Khan (2003) shows, this is not the case as countries have quite different energy consumption patterns (per unit of output). However, from a local perspective, it does not matter whether trading partners use different production technologies since imports displace domestic production in consumption. As long as the imports, from the domestic perspective, are dirtier than local production, then these imports will, all things equal, reduce the environmental impact of domestic production/consumption. Exports, on the other hand, use local technologies and inflict local damage. Taking the ratio of the two intensities can show whether trade is reducing the average pollution intensity of activity within a country. A ratio greater than one means that exports are dirtier than imports and that access to trade is increasing the average emissions from domestic activities. A ratio less than one means that exports are cleaner than imports and that access to trade is decreasing average emissions.

I test whether the pollution intensity of traded goods supports the PHE; that is, do richer countries, all things equal, have relatively cleaner exports than imports (a smaller PTT). Since capital-accumulation is important, I also test the FEH; do pollution intensities vary systematically with capital-labour ratios? The empirical approach follows Cole and Elliott (2003) and Bruneau (2008). I do this in three steps. I first see whether the pollution intensity of exports fall with income after accounting for differences in country specific effects and differences in capital-labour ratios. I then test whether the pollution intensity of imports rise with income. Finally, I test whether poorer countries have higher PTT indices than richer countries.

The results of the panel regression analysis find support for the FEH but little support for the PHE. For almost all pollutants in my study, higher relative capital-labour ratios lead to greater pollution intensity of exports and of imports but with the pollution intensity of exports higher than that for imports. That is, capital abundant countries have exports that tend to be dirtier than imports. On the other hand, higher relative incomes tend to lead to lower pollution intensity of exports and of imports. That is, there is only some evidence to show that poorer countries have exports that tend to be dirtier than imports.

The layout of the paper is as follows. In the next section I review some relevant literature. I follow this with data sources and a description of Canadian, China, and US trade intensities. I follow with panel regression analysis and results. Section 6 concludes.

2 Background:

The principal influences determining total emissions from production within an economy arise from scale, technique, and composition of production (Grossman and Krueger 1995, Copeland and Taylor 2003). The *scale effect* relates the size of the economy and total emissions. All things equal, the larger the economy, the higher the levels of pollution. The *technique effect* identifies the pollution intensity of production (emissions per unit of activity) employed within each firm/plant. The stricter the environmental regulation, the cleaner the technology used in production. The third influence, and the focus of this paper, is the *composition effect*. Changes in industrial structure, for a given scale and technique used in production, will also alter total emissions in an economy. Changes in the composition of national production will be reflected in its trade patterns.

Changes in the sectoral composition of trade can arise from a number of factors. First, changes in the internal composition of demand and productivity growth that take place in the process of development can alter the pattern of trade. Echevarria (2008) models this structural shift while Hazler and Echevarria (2006) document the shift empirically. Echevarria argues that economic development shifts consumption and production from agricultural and natural resource-based industries to manufacturing-based and, finally, to service-based industries. Hazler and Echevarria show that international trade mirrors the structural shift since the share of primary goods trade, relative to manufacturing, declines with development. The composition of manufacturing, and the trade in manufactured goods, will be linked to the structural shift in production and demand as the economy moves towards service-intensive production. The pollution intensity of traded manufacturing goods will reflect this structural shift and, presumably, lead to a cleaner sectoral mix of manufacturing industries.

Complementary to changes in demand is the effect of development on the stringency of environmental regulations. As countries get richer, given demand for environmental goods is a normal good, regulations and enforcement become stricter.[1] The effect is that environmental regulations will raise costs in dirty industries more and,

[1] The willingness to impose and enforce stricter environmental rules will be mediated through a political filter. See Farzin and Bond (2006) for example.

through rising prices, shift consumption/production toward cleaner industries.[2] The effect on the pollution intensity of trade is summarized in the *Pollution Haven Effect*; poor countries, due to weaker environmental rules, will acquire a comparative advantage in relatively dirty industries. Access to international markets will tend to expand these industries at the expense of cleaner industries. The converse holds for richer countries as their stricter environmental regulations provide a comparative advantage in clean industries. All thing equal, richer countries should have a cleaner mix of industries, a cleaner mix of exports, and a dirtier mix of imports.

Another factor is termed the *Capital Accumulation Hypothesis* (CAH). An increase in capital-labour ratios reduces the relative cost of capital intensive production and will shift production, and consumption, towards capital intensive sectors. Since more prosperous countries are also more likely to have higher capital-labour ratios, we would expect to see prosperous countries produce relatively more capital intensive goods. Cole and Elliott (2003) confirm that there is a significant positive correlation between capital intensity of production and pollution intensity for many pollutants. Hence, we would expect that increases in capital abundance would lead to increasing pollution intensity in manufacturing and in exports. Related to this is the *Factor Endowment Hypothesis* (FEH) (see Antweiler, Copeland, and Taylor 2001, Copeland and Taylor 2003, and Cole and Elliot 2003). Rich countries will have a comparative advantage in capital intensive industries given their greater capital abundance. Since these industries are generally more pollution intensive (Cole and Elliott 2003), trade will tend to expand dirty industries in the rich countries.

Altogether, we would expect relatively rich countries, all things equal, to have a cleaner mix of manufacturing industries which leads to a cleaner mix of exports. At the same time, rich countries will have demands shifted towards service-based sectors so will tend to have a cleaner mix of imports. Capital-abundant countries, all things equal, will have a dirtier mix of manufacturing industries.

[2] Since direct measures of environmental stringency are hard to find, per capita income is often used as a proxy. This means that we cannot differentiate between the direct effect of changes in demand that accompany rises in income and the indirect effects of environmental regulation that accompany rising incomes.

There are different ways to identify this shift in sectoral composition with respect to pollution. One way is to identify "dirty" industries and see if production or exports are rising faster than in "clean" industries. Khan (2003) takes this approach as he tests whether industries with higher pollution content are gaining import share relative to cleaner industries. Ederington et al (2004) also use this approach by taking a cross-sectional sample of SIC industries and testing whether tariff reductions, at the sectoral level, can account for some of the changes in the composition of production toward cleaner industries.

An alternative approach is to infer compositional changes through a proxy. Antweiler et al (2001) and Cole and Elliott (2003) take this approach. For instance, Cole and Elliott use a country's capital-labour ratio to capture changes in the composition of production (p 367).

A third approach, taken here, follows Bruneau (2008). Bruneau first calculates the average pollution intensity of manufacturing production in each country in each year. He uses emission coefficients and production data at the SIC level to calculate aggregate pollution intensity as the weighted average of emissions per dollar of production using sectoral production shares as weights. Higher pollution intensity means that the compositional structure of the economy is biased towards sectors with higher pollution intensities. He then tests whether the pattern of average pollution intensity across countries is influenced by exposure to trade, per capita income, and capital accumulation.

The advantage of a pollution intensity approach is that it accounts for the overall composition of production. We know from the Factor Proportions Model that, when the number of goods exceeds the number of factors, the pattern of trade can "break the chain of comparative advantage". That is, though a capital-abundant country may have net "exports" of capital, it is still possible that it imports some very capital-intensive goods. Trade theory cannot identify fully the pattern of trade. The best we can do is identify the average pattern. This is the point of the Factor Content Theorem. By aggregating all sectors into one measure of pollution intensity we account for broken chains of comparative advantage.

3 Data

Data is comprised of two parts. The first uses emission coefficients supplied by Hettige *et al* (1994) under the auspices of the *Industrial Pollution Projections Project* (IPPS). The IPPS database reports emission coefficients for US manufacturing industries using the *International System of Industrial Classification* (ISIC). Emission coefficients are reported for *ISIC sector 3* (*Manufacturing*) for sixteen different air, water, and soil pollutants. Coefficients are reported for different measures of industry size (output, value-added, and employment) at the two, three, and four-digit levels.

The IPPS accounts for 16 pollutants. It includes air pollutants (*Total Suspended Particulates (PT), Fine Particulates (PM10), Sulfur Dioxide (S02), Nitrogen Dioxide (NO2), Carbon Monoxide (CO),* and *Volatile Organic Compounds (VOC)*), water pollutants (*Biological Oxygen Demand (BOD)* and *Suspended Solids (TSS)*), indices of *Toxic Chemicals* (*Air, Land, Water, and Total*), and indices of *Bio-accumulative Metals* (*Air, Land, Water, and Total*). The first 12 pollutants can be interpreted as flow pollutants while the Bio-accumulative Metals can be interpreted as stock pollutants. Although an industry that is "dirty" on one pollutant tends to be dirty in the other pollutants as well, there is enough variation across pollutants that the relative rankings of industries changes depending on the pollutant used. Also, pollution intensities of the dirtiest industry can be many times the pollution intensities of the cleanest industry.

Following Antweiler (1996), I use US input-output data to attribute direct and indirect pollution of foreign sales from each sector (in pounds per million dollars of sales). For instance, exports from the *Industrial Chemicals* sector includes the direct SO2 emissions by that sector (8,907 lbs/$M taken directly from the IPPS database) as well as the pollution emitted by all other sectors that provide intermediate inputs to *Industrial Chemicals*. This means that the imputed SO2 emissions from exports of *Industrial Chemicals* rises to account for intermediate inputs (emissions rise to 8,998 lbs/$M). The effect of adding the imputed emissions to direct sectoral emissions reduces the variation across sectors since "clean" sectors use inputs from dirty sectors, and vice versa. However, as intermediate inputs from other sectors are usually a relatively small share of total inputs, the relative rankings of sectors using only direct emissions is the same as using imputed emissions.

Insert table 1 around here

Table 1 shows summary statistics used in the regressions below. I report only pollution intensity of exports. All 16 pollutants show a great deal of year to year and country to country variance. For the sample as a whole, the dirtiest countries have pollution intensity of exports that are from 5 to almost 60 times that of the cleanest countries. Even if we restrict to only one year (1990) the variation is still very large.

Ideally we would want country specific coefficients that vary over time rather than just US coefficients for one year. These are not available. However, as long as the ranking of industries is the same in each country in each time period, the magnitudes of the coefficients should not matter that much. A shift towards dirtier industries will be picked up by the pollution intensity measures regardless of the magnitudes of the coefficients. The problem arises when industry rankings in one country differ substantially from rankings in the US. One would expect that rankings in OECD countries would mirror that of the US since production technologies, and input-output structures, are likely quite similar. This need not necessarily be the case with developing countries since they may use quite different technologies than the US and so have quite different emissions performances. Unfortunately, it is not possible to say how much this matters.

The second data element comes from the World Bank's *Trade, Production and Protection Database* (Nicita and Olarreaga, 2006) which identifies the size of manufacturing industries as well as exports and imports by sector for OECD and Non-OECD countries between 1976 and 2004. I use only 58 countries. Industry size is reported at the three-digit ISIC 3 by gross output, value added, and the number of employees. Exports and imports are reported in US dollars at the three-digit level. See Table 2 for the countries used in the regression analysis.

I calculate the weighted average emission intensity in manufacturing trade for each country.[3] Since emission coefficients for each industry are identical across

[3] The use of output or trade shares to calculate intensity is not recommended by Hettige *et al* (p E-3, 1994). The problem is that changes in the value of output may reflect changes in relative prices and not in real activity. Industry employment, on the other hand, is more likely to reflect changes in real activity, particularly for poor countries, and so better reflect changes in emission intensity over time. However, one cannot attribute employment directly to trade.

countries, and are expressed as the average emission per unit of trade, the resulting pollution intensity distribution identifies the pure composition effect across countries; emission intensity varies only because the composition of trade varies across countries and over time.

Supplemental data such as real PPP-adjusted GDP per capita and an openness index comes from the *Penn World Table Version 6.2* (Heston, Summers, and Aten, 2002). Capital-labor ratios (KL) come from Easterly and Levine (1999). The lack of capital stock data restricts my sample to the period 1976-1990 but does provide data for 57 countries (see table 2 for the list of countries included). This provides a very broad cross-section with many developing countries included. In most cases, there is the full fifteen years of data. Only a handful of countries, primarily the poorer ones, have less data.

4 Pollution Intensity of Trade for SO2

This section, in the flavour of Khan (2003), shows how pollution intensity of import, exports, and production has changed for the countries in my sample. For brevity, I report only the results for Sulfur Dioxide (SO2). The pattern for other pollutants is similar. I begin with changes for Canada, China, and the US between 1978 and 1998. Later, I show SO2 data for all my countries for 1990 and 1998.

For Canada, China, and the US, the data confirms that economic activity with respect to SO2 is shifting to cleaner sectors though at different rates. As shown in Figure 1, US pollution intensity of imports (measures in lbs per million dollars) is higher than exports though both have decreased over the period. US production tends to be dirtier than its exports and exports. The fact that imports are “dirtier” than exports lends support to the idea that the US has outsourced dirty production to other countries. That imports are getting cleaner suggests that the degree of outsourcing is getting smaller over time. The puzzle is that exports are also getting cleaner at the same time.

Unlike the United States (see Figure 2), Canadian exports (primarily to the US) tend to be much dirtier than its imports (also primarily from the US). Nonetheless, the pollution intensities of exports and production are declining though not for imports which is largely unchanged over the period.

China is a bit different. Its pollution intensity in production is higher than the levels in Canada and the US but has fallen somewhat. Its import and export intensities are lower than its production intensity and, by the end of the period, similar in magnitude to those in Canada. However, unlike Canada, import pollution intensities are much higher than export pollution intensities suggesting China is not a pollution haven.

Insert figures 1, 2, and 3 around here

We can now compare the PTT. This is shown in figure 4 for Canada, China, and the US. For the US, exports are cleaner than imports (PTT values are less than one) but are getting cleaner at a slower rate (PTT is rising) so that by the end of 1998 exports were almost as dirty as imports.. Canada, on the other hand, has a PTT above one but declining markedly. China tends to have a PTT even lower than that for the US though it is not changing much.

Insert figure 4 around here

Figures 1 through 4 have an interesting interpretation. Canada and the US are each others largest trading partners and manufacturing is highly integrated across the border. That Canada's pollution intensity of exports mirror the US pollution intensity of imports (and vice versa) is no surprise. As Canada's exports to the US tend to be dirtier than Canada's imports from the US, Canada might be viewed as a US pollution haven. However, that Canada's trade pollution index is falling, while it is rising in the US over the same period, suggests that the tables are turning with the US becoming Canada's pollution haven. It does not appear to be the case China is a pollution haven as its exports tend to be much cleaner than its imports. However, opening to trade may alter this as the PTT is rising.

We can do the same as the above for all the countries we have data for. Table 2 shows the results for SO2 for all the countries in my sample (67 countries) but for the period 1990 to 1998 where we have most data. Countries are ranked from the highest to lowest PTT. For example, Chile has an export pollution intensity over 4 times their import pollution intensity. At the other extreme Nepal has an export pollution intensity about 1/3rd their import pollution intensity.

Also reported are the changes in the PTT between 1990 and 1998. In half the cases, the PTT is rising. However, for the 27 countries that had a PTT above 1 in 1990, 23 saw it fall to 1998. For the 35 countries that had a PTT less than 1 in 1990, 25 saw it rise. Overall, the PTT fell from 1990 to 1998 as did the dispersion across countries. It would appear that PTTs are converging over time.

An initial impression is that it is the poorest countries that tend to have the lowest PTT, but not always. The correlation between GDP per capita (adjusted for PPP) and PTT is close to zero but for imports it is negative and statistically significant. However, the correlation between GDP per capita and the PTT is very close to zero suggesting that the cross-country pattern of PTT is independent of per capita income. A similar pattern emerges for capital-labour ratios and PTT. The PTT seems to be driven more by the pollution intensity of exports rather than imports, though both are statistically significant.

Insert table 2 around here

5 Regression Analysis

Table 2 showed that the composition of trade with respect to SO2 intensity differs across countries. It is shifting over time and is generally moving towards cleaner industries, though not for all countries. However, how much is due to differences in income, capital, exposure to trade, social/political institutions, and ability to absorb pollution is not clear. To understand these factors we need to run regressions.

The question I want to ask is whether the composition of trade with respect to pollution, and the resulting pollution intensity of trade, is driven by the *Pollution Haven Effect* and/or the *Factor Endowment Hypothesis*. I follow the approach of Cole and Elliott (2003) though focus only on the trade-induced composition effects that they identify. The regression to be tested is:

$$P_{it} = (\alpha + \delta_i F_i) + \beta_1 TIME_t + \beta_2 O_{it} + \beta_3\left[O_{it}(\frac{Y_{it}}{\overline{Y}_t})\right] + \beta_4\left[O_{it}(\frac{Y_{it}}{\overline{Y}_t})^2\right] + \beta_5\left[O_{it}(\frac{KL_{it}}{\overline{KL}_t})\right] + \beta_6\left[O_{it}(\frac{KL_{it}}{\overline{KL}_t})^2\right] + \beta_7\left[O_{it}(\frac{KL_{it}}{\overline{KL}_t})(\frac{Y_{it}}{\overline{Y}_t})\right] + e_{it} \quad (1)$$

Where P_{it} denotes the pollution intensity of trade in country *i* in year *t*. Pollution intensity can be for exports, imports, or PTT. F_i denotes effects specific to country *i*, $TIME_t$ is a time dummy with 1976 as the base, O_{it} is the openness index of country *i,* year *t*, Y_{it} is the real, PPP adjusted, per capita income in country *i,* year *t*, KL_{it} is the capital-labour ratio in country *i,* year *t,* $\overline{Y}_t$ is the mean per capita income for the world in period *t*, and $\overline{KL}_t$ is the mean capital-labour ratio for the world in period *t*. The regress is run in levels.

The first part of equation 1 captures the constant and country-fixed effects. These country effects can arise from differences in political institutions (as in Farzin and Bond 2006) or the absorptive capacity of national environments. Ideally we would account for these differences directly. However, given the breadth of countries used in the regressions, there is no good data that allows us to identify these effects for all the countries and over the time period studied. The country fixed effects are an attempt to capture the heterogeneity that arises across countries.

The time dummy is used to capture secular changes in global demands or other factors that change systematically over time for all countries. Openness by itself need not promote cleaner industries (as in Antweiler et al 2001) so I have no a priori expectations as to its sign. It turns out that the estimated values are almost always positive and significant for exports and imports. In other words, more open countries tend to have dirtier trade in both directions. I can not speculate why this is the case.

The interaction of openness with relative income, as in Cole and Elliott (2003), captures the effects of comparative advantage. The poorer one is, relative to other trading nations, the greater the comparative advantage in dirty industries. The quadratic terms captures the possibility that comparative advantages are non-linear in relative incomes. For a given relative income, the more open one is, the stronger the forces of comparative advantage and the more likely that a poor country will express its comparative advantage in dirty production. If the *Pollution Haven Effect* is present for exports, then $\beta_3 < 0$ and $\beta_4 > 0$. The converse holds for imports as well as for the PTT.

Similarly, the greater the capital-labour ratio, relative to other trading nations, the greater the comparative advantage in capital intensive, and presumably dirty, industries. Again, these effects are mediated by the openness of a country. The less open, the less comparative advantage matters, and the less important a country's relative position is. If the *Factor Endowment Effect* is present for exports, then $\beta_6 > 0$ and $\beta_6 < 0$. The converse holds for imports as well as for the PTT.

One can calculate the relative position of a country in two ways. First, as in Cole and Elliott (2003), one can include the deviation of per capita income and capital-labor ratios from the world as a whole for the entire sample period.[4] Hence all countries are positioned relative to one global average for the entire sample. However, what matters for comparative advantage is the relative position of a country at a point in time relative to its trading partners. This suggests that the alternative approach is to calculate the deviation of per capita income and capital-labor ratios from the world mean for each year individually. I take this approach.

I run three sets of regressions for the pollution intensity of exports, imports, and the index of trade pollution intensity. OLS regressions were run for each pollutant using White's (1980) heteroskedastic-consistent covariance matrix estimation to correct for an

[4] One includes all countries for which data is available and not just those in the sample.

unknown form of heteroskedasticity. Because relative income and quadratic relative income terms are correlated, I test for the joint hypothesis that both are zero rather than rely on individual t-statistics. I do this also for relative capital-labour.

The full regression results are reported in the appendix (Tables A1-A3). For all pollutants, relative incomes and relative capital-labour ratios are statistically significant at all levels for exports, imports, and the PTT. Rising relative incomes tend to lower pollution intensity of both exports and imports though at decreasing rates. The impact on the PTT becomes mixed but is generally negative, at least at lower relative incomes. At the same time, rising relative capital-labour lead to more pollution intense exports as well as imports, again at diminishing rates. Together, rising relative capital-labour raises PTT. These results are consistent with the observation that imports and exports seem to be getting cleaner for most countries.

To explore the non-linear relationships, we can look at elasticities at different levels of relative income. These are reported in tables 3 and 4. To find the elasticity of the PTT with respect to relative income, I first break the sample into 10 relative income ranges. For each range I identify the average relative income, PTT, relative KL ratio, and openness index. This allows me to ask whether a representative poor country (say with a per capita income less than 25% of the mean and an average openness and capital-labour ratio consistent with that income range) will experience a worsening environment if they grow faster or slower than average. If the PHH holds at all levels, then the elasticity of the PTT should be negative; rising relative incomes should lead to lower PTT values. Similarly, if the FEH holds, then rising relative capital-labour ratios should raise the PTT.

Insert tables 3 and 4around here

In most cases however, we get u-shaped elasticities. For instance, consider *Total Suspended Particulates* (PT). At low relative incomes, a rising income leads to a statistically significant reduction in the PTT. However, at high incomes, further increases lead to statistically significant higher PTT values. This pattern emerges in almost all cases. The exceptions are *Volatile Organic Compounds* (VOC) and *Toxic Water Chemicals*. In these cases, the elasticities start off positive but become negative. So a simple characterization that rich countries are off-shoring dirty production to poor countries is not consistent with the data. Rather, it appears more accurate to say that above average income growth in rich countries results in a compositional shift in trade towards dirtier exports and/or cleaner imports.

A similar nuanced result applies to the FEH. When capital scarce countries see their capital-labour ratios rise relative to their peers, their PTT worsens. However, for capital abundant countries, rising relative capital-labour ratios leads to a lower PTT. In only one case, *Toxic Water Chemicals*, do higher capital-labour ratios lower the PTT in capital-scarce countries.

6 Conclusion and Discussion

Khan (2003) and Ederington et al (2004) present a puzzle; the composition of US trade is becoming cleaner in both directions. They showed that US exports are shifting towards less pollution intensive industries at the same time that imports are as well.

In this paper, data for exports and imports show that higher relative incomes lead to cleaner trade, but only for relatively poor countries. For rich countries, higher relative incomes lead to dirtier trade on average. On the other hand, higher relative capital-labour ratios lead to dirtier trade in both directions though for the most capital abundant countries, rising relative capital-labour ratios leads to cleaner trade.

I conclude, like Khan and Ederington et al, that the data does not support the *Pollution Haven Effect*. It does not appear to be the case that poor countries

Rather, capital accumulations appear to be a dominate factor in determining the pollution intensity of trade; capital abundant countries tend to have dirtier trade, both for imports and exports, with the pollution intensity of exports higher that that for imports.

The results here are broadly consistent with Bruneau (2008). He found, for the same set of countries here, that the composition of production was primarily driven by domestic factors (capital accumulation and income growth). Trade-induced factors were not a dominant factor though there was some evidence that the composition of domestic production was influenced by relative capital-labour ratios. There was little evidence supporting the pollution haven hypothesis.

How do we interpret these results? One way is to recognize that higher relative incomes might be capturing two different effects. The first is tied to comparative advantages in dirty/clean production. This is the pollution haven effect; poorer countries will tend to have weaker environmental regulations and so have a comparative advantage in dirty goods. So we expect the pollution intensity of exports to fall with relative income. We also expect the pollution intensity of imports to rise with relative income. However, as Echevarria (2008) argues, countries are going through structural changes as they become richer. Their consumption of manufactures and services, as a share of national income, rises with income. Hence, all things equal, we would expect rich countries to produce and export cleaner goods on average. This works in the same direction as environmental regulations. However, since rich country spending is also biased towards clean goods, we also expect to see imports to be cleaner as well. This works in the opposite direction as environmental regulations. It might be the case that the structural change effect dominates the pollution haven effect in some instances. So even if differences in environmental standards impact the composition of trade, it is not likely the dominant factor.

What about relative capital-labour ratios? Overall, higher capital-labour ratios lead to dirtier exports and imports with exports dirtier than imports. This is likely driven by intra-industry trade within manufacturing. For example, Canada's largest export sector (autos and auto parts) is also our largest import sector. Overall, the correlation between the volume of imports and the volume of exports across the three-digit SIC sectors was 0.88 in 1999. For the US it was 0.98 while for China it was 0.70. As world supply chains have strengthened, the correlation between exports and imports has risen for virtually all countries between 1976 and 1999 (based on the World Bank dataset used here) though poorer countries typically have lower correlations. So factors, such as the relative capital-labour ratio, that affect the composition of production within countries will simultaneously affect both imports and exports to similar degrees. That the relationship is stronger for exports than imports is not altogether a surprise.

Some caveats apply. There is a growing literature that does identify pollution haven effects but these rely on endogenizing income and protection. That is, policies that alter pollution intensity can also affect income growth. Hence national income may not be exogenous to pollution performance. For instance, countries may impose weaker environmental policies which simultaneously induce higher growth rates in pollution intensive industries and higher GDP growth rates (though not necessarily higher welfare growth). I have not accounted for this possible endogenous response but plan to do this so the next step.

Second, I use the pattern of trade to identify pollution haven effects. However, as Ederington et al (2004) point out, what we really want to know is whether trade liberalization (eg reductions in tariffs) induces shifts in the composition of production and trade such that rich countries lose market share in dirty industries. The World Bank data provides some data on tariffs and non-tariff barriers so this avenue may be fruitful for future research.

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FIGURE 1: Pollution Intensity of Sulfur Dioxide (SO2) in Production, Exports, and Imports for the US: 1978 - 1998

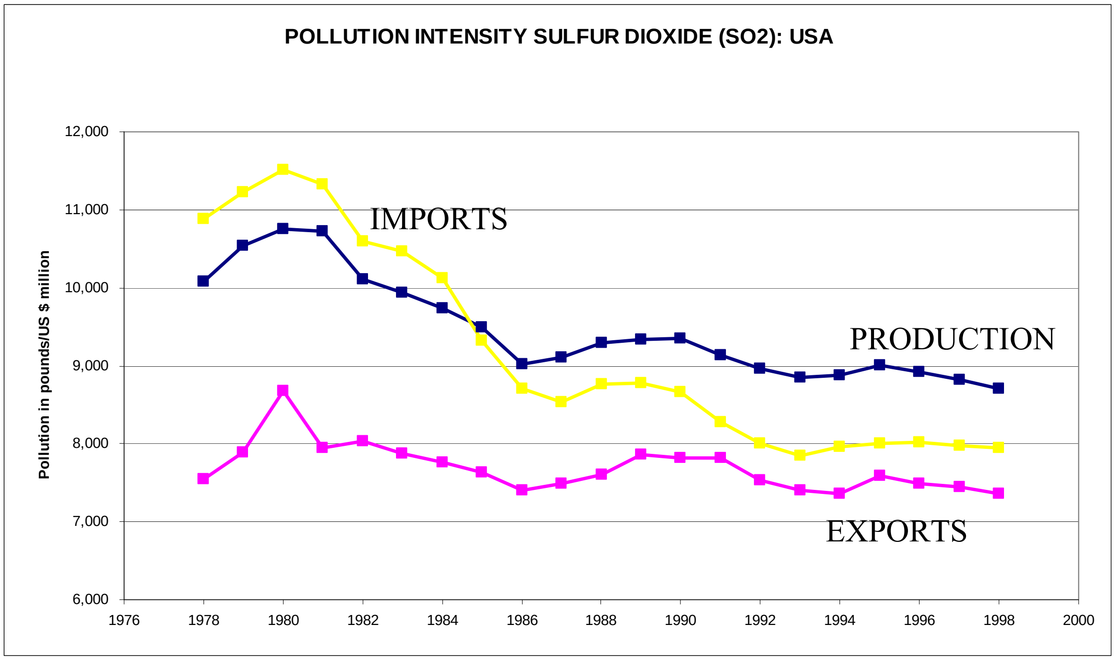

FIGURE 2: Pollution Intensity of Sulfur Dioxide (SO2) in Production, Exports, and Imports for Canada: 1978 - 1998

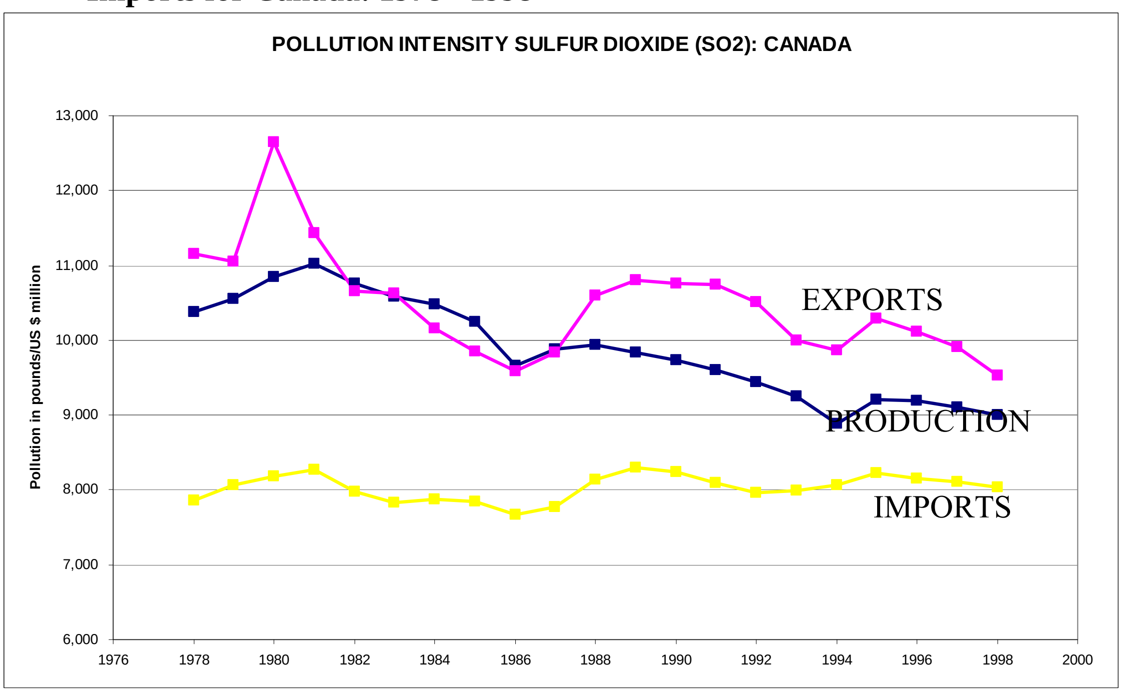

FIGURE 3: Pollution Intensity of Sulfur Dioxide (SO2) in Production, Exports, and Imports for China: 1978 - 1998

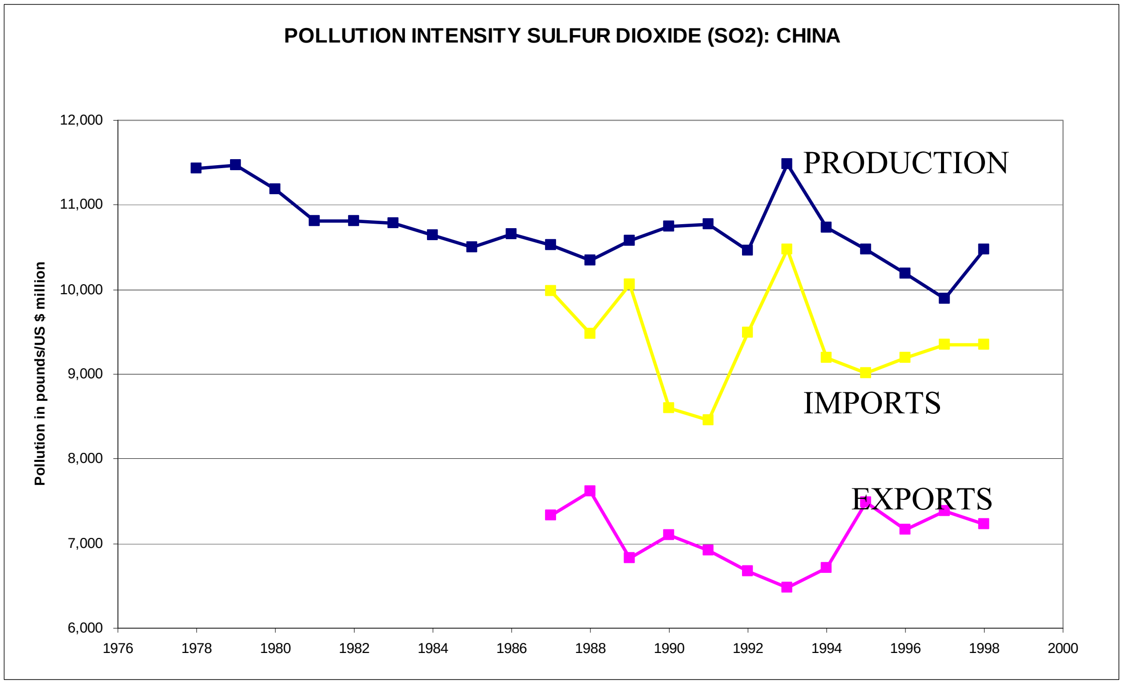

FIGURE 4: PTT (Sulfur Dioxide (SO2)) for Canada, China, and the US: 1978-1998

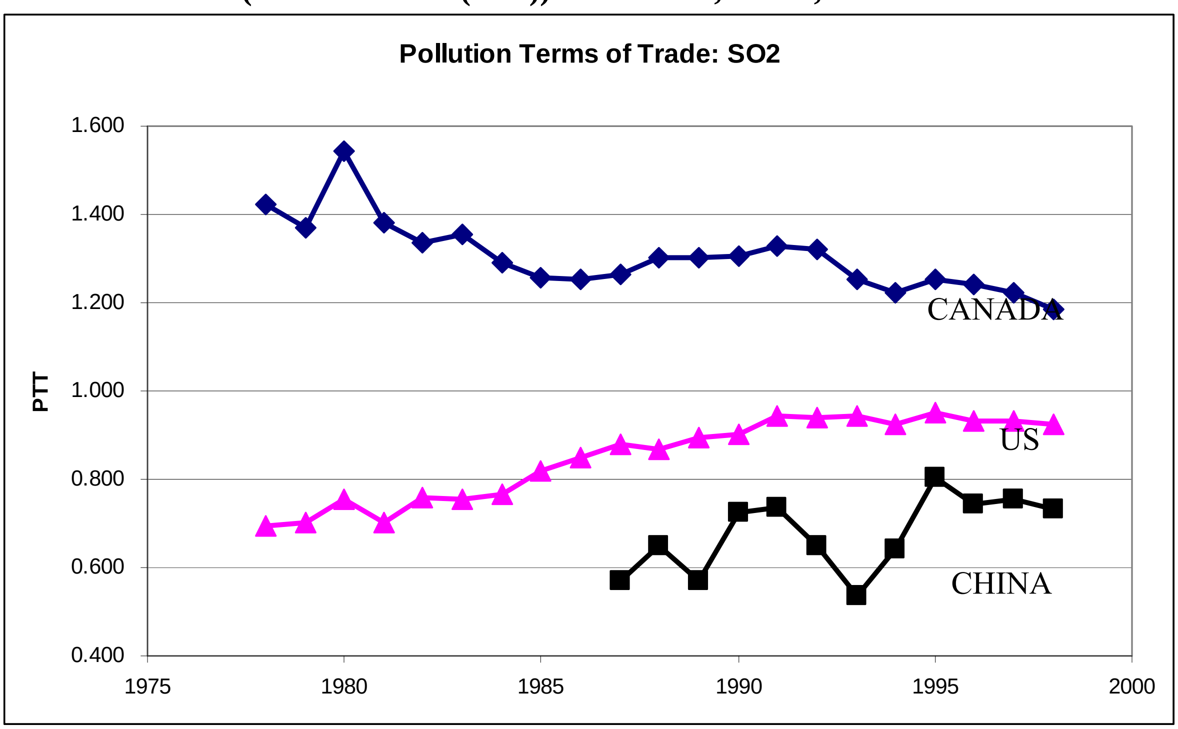

TABLE 1: Descriptive Statistics:

1976-1998, N = 1185	Pollution Intensity				
	MEAN	**MAX**	**MIN**	**MAX/ MIN**[2]	**MAX/ MIN**[3]
POLLUTANTS (lbs per $1000 of exports)					
AIR					
Volatile Organic Compounds (VOC)	3,606	11,394	1,970	6	4
Total Suspended Particulates (PT)	2,068	5,190	780	7	4
Carbon Monoxide (CO)	7,914	26,930	2,722	10	6
Sulphur Dioxide (S02)	10,539	54,801	3,482	16	10
Fine Particulates (PM10)	980	2,425	278	9	7
Nitrogen Oxides (NO2)	4,767	13,977	2,462	6	3
WATER					
Total Suspended Solids (TSS)	19,846	83,247	3,009	28	22
Biological Oxygen Demand (BOD)	1,271	4,308	403	11	6
TOXIC CHEMICALS					
Air (TOXAIR)	294	692	118	6	5
Land (TOXLAND)	6,011	17,106	2,370	7	5
Water (TOXWAT)	3,731	11,960	1,378	9	6
Total (TOXTOT)	2,024	4,925	929	5	4
BIO-ACCUMULATIVE METALS					
Air (METAIR)	5	14	2	9	6
Land (METLAND)	1,175	9,725	175	56	34
Water (METWAT)	1,130	9,428	165	57	34
Total (METTOT)	40	288	7	40	24
OTHER VARIABLES					
Real GDP per capita -PPP adjusted (Y)	10,071	365	32,298	88	39.7
OPENNESS (O)	65	12	425	36	23.9
Capital-Labour ratio (K/L)	34,098	329	105,970	322	83.3

1. Data Sources: IPPS, *World Trade Database, Penn World Table Version 6.2*, Easterly and Levine (1999).
2. Ratio of Maximum to Minimum (Max/Min) is based on entire 1976-1990 sample.
3. Ratio of Maximum to Minimum (Max/Min) is based on 1990 data only.

TABLE 2: Pollution Intensity of Imports and Exports for SO2, 1990, All countries

Country	Y_{PPP} 1990	KL 1990	EXPORT Intensity 1990	IMPORT Intensity 1990	PTT 1990	PTT 1998	PTT change
CHILE	7,120	639	37,033	8,524	4.34	3.56	-0.18
BOLIVIA	2,574	114	28,817	8,402	3.43	1.11	-0.68
PERU	3,506	326	26,493	9,065	2.92	3.12	0.07
VENEZUELA	7,445	368	27,379	9,767	2.80	2.54	-0.09
AUSTRALIA	20,372	3,840	16,442	7,776	2.11	2.28	0.08
S.AFR.CUS.UN	7,715	662	15,435	7,553	2.04	1.27	-0.38
CAMEROON	2,699	145	20,489	10,027	2.04	1.45	-0.29
TRINIDAD TBG	9,063	332	18,083	9,017	2.01	1.87	-0.07
EGYPT	3,389	222	15,488	8,676	1.79	1.55	-0.13
NORWAY,SB,JM	23,958	7,068	18,220	11,160	1.63	1.72	0.06
POLAND	5,897	539	14,609	9,813	1.49	1.11	-0.25
MEXICO	6,864	767	11,827	8,606	1.37	0.85	-0.38
ROMANIA	5,677	619	13,497	10,052	1.34	1.31	-0.03
GREECE	12,000	2,168	11,920	8,932	1.33	1.41	0.06
CANADA	21,757	3,831	10,755	8,245	1.30	1.18	-0.09
HONDURAS	2,357	134	14,300	12,195	1.17	0.89	-0.24
SINGAPORE	19,466	6,117	10,238	8,960	1.14	1.00	-0.13
SPAIN	15,418	3,490	9,738	8,556	1.14	1.04	-0.09
FINLAND	20,000	7,023	9,971	9,080	1.10	1.08	-0.02
NETHERLANDS	20,989	5,711	9,645	8,905	1.08	1.02	-0.06
AUSTRIA	22,224	6,539	9,481	8,942	1.06	1.03	-0.03
UNTD.KINGDOM	19,849	3,211	9,059	8,776	1.03	1.00	-0.03
INDONESIA	2,918	224	10,391	10,148	1.02	0.83	-0.19
NEW ZEALAND	17,139	3,041	9,337	9,196	1.02	0.96	-0.06
SWEDEN	21,782	5,522	9,408	9,333	1.01	0.98	-0.03
ARGENTINA	8,195	735	10,164	10,183	1.00	0.95	-0.05
ECUADOR	4,443	230	10,538	10,583	1.00	0.77	-0.23
PHILIPPINES	3,214	257	9,472	9,599	0.99	0.77	-0.22
KUWAIT	16,559	NA	8,103	8,350	0.97	2.59	1.66
FRANCE,MONAC	21,343	5,620	8,995	9,414	0.96	0.96	0.00
TURKEY	4,767	623	9,599	10,169	0.94	0.88	-0.07
COLOMBIA	5,438	345	10,252	10,863	0.94	1.00	0.06
JORDAN	3,534	536	8,542	9,143	0.93	0.95	0.02
USA	27,097	4,320	7,822	8,668	0.90	0.93	0.03
GERMANY	21,307	6,110	8,544	9,507	0.90	0.95	0.06
KENYA	1,353	66	9,540	10,903	0.88	0.86	-0.02
HONG KONG	21,963	4,777	6,169	7,052	0.87	0.93	0.07
HUNGARY	10,058	957	9,065	10,456	0.87	0.54	-0.38
MOROCCO	3,647	317	7,952	9,426	0.84	0.91	0.08
IRELAND	13,444	3,210	7,052	8,447	0.83	0.97	0.16
CHINA	1,672	124	7,103	8,596	0.83	0.77	-0.06
ITALY	19,560	3,939	8,113	9,824	0.83	0.85	0.03

PORTUGAL	13,607	2,354	6,898	8,566	0.81	0.81	0.01
CYPRUS	14,686	NA	7,040	9,015	0.78	0.96	0.23
MALAYSIA	6,890	914	7,233	9,351	0.77	0.79	0.02
DENMARK	22,185	6,126	7,033	9,106	0.77	0.84	0.08
ETHIOPIA	464	12	5,678	7,807	0.73	NA	NA
PANAMA	6,111	452	5,720	8,221	0.70	0.91	0.30
KOREA REP.	9,593	2,836	7,204	10,451	0.69	0.82	0.18
COSTA RICA	6,349	578	6,902	10,715	0.64	0.72	0.12
TAIWAN	11,248	NA	7,035	10,947	0.64	0.77	0.20
JAPAN	21,703	12,647	7,519	12,004	0.63	0.85	0.36
MACAU	21,861	3,200	4,500	7,412	0.61	0.56	-0.07
SRI LANKA	2,750	150	4,669	8,090	0.58	NA	NA
URUGUAY	7,932	465	5,101	9,088	0.56	0.69	0.23
THAILAND	4,864	776	5,702	10,237	0.56	0.70	0.25
MALAWI	683	55	5,132	9,661	0.53	NA	NA
GUATEMALA	3,501	168	5,663	10,877	0.52	0.78	0.50
INDIA	1,898	74	7,016	14,328	0.49	0.55	0.13
PAKISTAN	2,202	85	4,649	11,034	0.42	0.45	0.07
NEPAL	1,106	NA	4,072	10,760	0.38	0.39	0.03
BANGLADESH	1,577	48	3,897	10,594	0.37	0.35	-0.05
ARMENIA	NA	680	NA	NA	NA	0.90	NA
BULGARIA	NA	219	NA	NA	NA	1.76	NA
IRAN-ISLAM.R	4,459	216	NA	NA	NA	1.11	NA
LATVIA	NA	1,803	NA	NA	NA	0.83	NA
REP.MOLDOVA	NA	NA	NA	NA	NA	0.51	NA
MEAN	**10,404**	**2,075**	**10,544**	**9,502**	**1.14**	**1.09**	
STDEV	**7,915**	**2,593**	**6,350**	**1,265**	**0.73**	**0.60**	

CORRELATIONS (significant at the 1% level, * significant at the 5% level)**

	Yppp	**KL**	**EXPORT Intensity**	**IMPORT Intensity**	**PTT 1990**	**PTT 1998**
Y_{PPP} 1990	1.0000	0.8752**	-0.0963	-0.3102**	-0.0531	0.0570
KL 1990		1.0000	-0.1418	-0.0687	-0.1310	-0.0579
EXPORT Intensity 1990			1.0000	-0.1080	0.9817**	0.8035**
IMPORT Intensity 1990				1.0000	-0.2678*	-0.2982**
PTT 1990					1.0000	0.8155

1 Y_{PPP}: Per capita GDP in constant $US 1987 (adjusted for PPP). Taken from PENN World Tables 6.2.
2 KL: Capital-Labour ratios in $US per worker taken from Easterly and Levine (1999).

TABLE 3: PTT Elasticity with respect to Relative Income

Relative Income range	VOC	PT	CO	SO2	PM10	NO2	TSS	BOD	MET air	MET land	MET water	MET total	TOX air	TOX land	TOX water	TOX total
0 to 0.25	0.017 *	-0.024 ***	-0.007	-0.008	-0.057 ***	0.003	-0.029 ***	-0.003	-0.021 ***	-0.019 ***	-0.002	-0.019 ***	0.009	0.007	0.018 **	0.008
0.25 to 0.50	0.047 *	-0.080 ***	-0.026	-0.034	-0.146 ***	0.008	-0.099 ***	-0.007	-0.115 ***	-0.120 ***	-0.008	-0.119 ***	0.026	0.025	0.063 **	0.027
0.50 to 0.75	0.100 *	-0.166 ***	-0.052	-0.066	-0.298 ***	0.021	-0.194 ***	-0.006	-0.225 ***	-0.233 ***	-0.020	-0.231 ***	0.044	0.045	0.112 **	0.047
0.75 to 1.00	0.088 *	-0.153 ***	-0.047	-0.037	-0.359 ***	0.025	-0.272 ***	0.011	-0.272 ***	-0.284 **	-0.034	-0.281 **	0.042	0.045	0.095 *	0.047
1.00 to 1.25	0.103	-0.191 ***	-0.069	-0.052	-0.398 ***	0.014	-0.323 ***	0.030	-0.248 **	-0.225 **	-0.048	-0.224 **	0.052	0.052	0.116 *	0.054
1.25 to 1.50	0.073	-0.140 ***	-0.043	-0.016	-0.349 ***	0.002	-0.175 **	0.066	-0.107 *	-0.086	-0.048	-0.086	0.043	0.038	0.070	0.041
1.50 to 1.75	0.100	-0.072	-0.032	0.154	-0.382 ***	0.028	-0.331	0.170 ***	0.029	0.133	-0.163	0.127	0.016	0.030	-0.037	0.019
1.75 to 2.00	0.004	0.061 ***	0.018	0.092 ***	0.015	0.015	0.001	0.142 ***	0.099 ***	0.119 ***	-0.082 **	0.118 ***	-0.027	-0.011	-0.096 ***	-0.020
2.00 to 2.50	-0.017	0.250 ***	0.082 *	0.266 ***	0.275 ***	0.042	0.141	0.289 ***	0.473 ***	0.594 ***	-0.129 **	0.585 ***	-0.087 **	-0.053	-0.282 ***	-0.079 *
2.50 and up	0.002	0.158 ***	0.048 **	0.124 ***	0.169 ***	0.050	0.049 **	0.127 ***	0.141 ***	0.164 ***	-0.047	0.162 ***	-0.081 **	-0.040	-0.177 ***	-0.068 *

Note: *** is significant at the 1% level, ** is significant at the 5% level, and * is significant at the 10% level.

TABLE 3: PTT Elasticity with respect to Relative Income

Relative Income range	VOC	PT	CO	SO2	PM10	NO2	TSS	BOD	MET air	MET land	MET water	MET total	TOX air	TOX land	TOX water	TOX total
0 to 0.25	+	-			-		-		-	-		-			+	
0.25 to 0.50	+	-			-		-		-	-		-			+	
0.50 to 0.75	+	-			-		-		-	-		-			+	
0.75 to 1.00	+	-			-		-		-	-		-			+	
1.00 to 1.25		-			-		-		-	-		-			+	
1.25 to 1.50		-			-		-		-							
1.50 to 1.75					+			+								
1.75 to 2.00		+		+				+	+	+	-	+			-	
2.00 to 2.50		+	+	+	+			+	+	+	-	+	-		-	-
2.50 and up		+	+	+	+		+	+	+	+		+	-		-	-

TABLE 4: PTT Elasticity with respect to Relative Capital-Labour Ratios

Relative Income range	VOC	PT	CO	SO2	PM10	NO2	TSS	BOD	MET air	MET land	MET water	MET total	TOX air	TOX land	TOX water	TOX total
0 to 0.25	0.018 ***	0.018 ***	0.013 ***	0.020 ***	0.018 ***	0.020 ***	0.010	0.000	0.012 *	0.010	0.001	0.010	-0.004	0.002	-0.013 **	-0.001
0.25 to 0.50	0.063 ***	0.075 ***	0.054 ***	0.094 ***	0.075 ***	0.073 ***	0.047	-0.001	0.063 *	0.060	0.010	0.059	-0.016	0.010	-0.042 **	-0.002
0.50 to 0.75	0.106 ***	0.139 ***	0.095 ***	0.161 ***	0.128 ***	0.122 ***	0.080	0.000	0.116 *	0.112	0.021	0.111	-0.026	0.019	-0.067 **	-0.002
0.75 to 1.00	0.119 **	0.161 ***	0.107 ***	0.179 ***	0.166 ***	0.146 ***	0.108	0.002	0.124 *	0.114	0.031	0.113	-0.024	0.022	-0.062	0.000
1.00 to 1.25	0.170	0.241 ***	0.207 ***	0.284 ***	0.290 ***	0.211 ***	0.266 *	0.005	0.252 *	0.226	0.096	0.226	-0.030	0.048	-0.082	0.011
1.25 to 1.50	0.058	0.141 ***	0.117 ***	0.115	0.219 ***	0.096	0.195 **	0.005	0.144 **	0.124	0.104 *	0.124	-0.002	0.039	-0.007	0.021
1.50 to 1.75	0.023	0.099 ***	0.085 ***	0.051	0.219 ***	0.064	0.169 **	0.009	0.073	0.056	0.123 **	0.057	0.008	0.034	0.023	0.024
1.75 to 2.00	-0.054	0.018	0.030	-0.028	0.139 ***	-0.031	0.141 **	0.014	0.057	0.044	0.110 ***	0.045	0.033 *	0.025	0.099	0.031 *
2.00 to 2.50	-0.116 *	0.000	0.028	-0.083 *	0.140 **	-0.079	0.163 **	0.029	0.074	0.059	0.139 ***	0.059	0.050 **	0.034	0.135 ***	0.044 **
2.25 to 2.50	-0.152 **	-0.046 **	-0.003	-0.130 **	0.088	-0.120 **	0.124 **	0.041	0.041	0.030	0.130 ***	0.031	0.066 ***	0.028	0.182 ***	0.048 **
2.50 to 3.00	-0.671 **	-0.304 ***	-0.122 **	-0.540 ***	0.066	-0.561 ***	0.232	0.141	0.000	-0.011	0.313	-0.010	0.210	0.047	0.539 **	0.127
3.00 and up	-0.408 ***	-0.289 ***	-0.120 **	-0.494 ***	-0.039	-0.390 ***	0.108	0.097	-0.058	-0.063	0.142 ***	-0.062	0.112 ***	0.015	0.248 ***	0.064

Note: *** is significant at the 1% level, ** is significant at the 5% level, and * is significant at the 10% level.

TABLE 4: PTT Elasticity with respect to Relative Capital-Labour Ratios

Relative KL range	VOC	PT	CO	SO2	PM10	NO2	TSS	BOD	MET air	MET land	MET water	MET Total	TOX air	TOX land	TOX water	TOX total
0 to 0.25	+	+	+	+	+	+			+						-	
0.25 to 0.50	+	+	+	+	+	+			+						-	
0.50 to 0.75	+	+	+	+	+	+			+						-	
0.75 to 1.00	+	+	+	+	+	+			+							
1.00 to 1.25	+	+	+	+	+	+	+		+							
1.25 to 1.50		+	+		+	+	+		+		+					
1.50 to 1.75		+	+		+		+		+		+					
1.75 to 2.00					+		+				+		+			+
2.00 to 2.50	-			-	+		+				+		+		+	+
2.25 to 2.50	-	-		-		-	+				+		+		+	+
2.50 to 3.00	-	-	-	-		-									+	
3.00 and up	-	-	-	-		-					+		+		+	

APPENDIX

TABLE A1: Regression Results: dependent variable = pollution intensity of EXPORTS (country fixed effects suppressed)

	VOC	PT	CO	SO2	PM10	NO2	TSS	BOD	MET air	MET land	MET water	MET total	TOX air	TOX land	TOX water	TOX total
n=	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185	1185
R^2 adj	0.862	0.881	0.867	0.864	0.782	0.884	0.841	0.879	0.849	0.849	0.841	0.849	0.821	0.833	0.815	0.826
constant	**3344**	**1740**	**7384**	**9189**	**841**	**4054**	**18593**	**1084**	**38**	**1061**	**5**	**1105**	**2052**	**3592**	**290**	**5898**
prob	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TIME	**-22.11**	**-18.70**	**-58.73**	**-143.6**	**-4.09**	**-33.83**	**-122.0**	**-11.07**	**-0.50**	**-15.91**	**0.00**	**-16.42**	**-1.78**	**-15.59**	**1.05**	**-16.18**
prob	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.392	0.000	0.186	0.000	0.000	0.001
OPEN	**-9.70**	**-0.52**	**-4.78**	**-18.46**	**3.75**	**-7.75**	**47.37**	**-3.13**	**0.01**	**-0.11**	**0.00**	**-0.10**	**0.19**	**-2.23**	**0.19**	**-1.80**
prob	0.000	0.671	0.326	0.027	0.001	0.002	0.043	0.001	0.895	0.944	0.211	0.951	0.829	0.294	0.351	0.564
OY/$\overline{Y}_t$	**-2.26**	**-12.74**	**-14.03**	**-25.13**	**-10.88**	**-15.33**	**-46.47**	**-5.95**	**-0.04**	**-0.88**	**-0.01**	**-0.92**	**-0.91**	**-3.33**	**-0.33**	**-4.51**
prob	0.627	0.000	0.081	0.064	0.000	0.003	0.281	0.000	0.622	0.704	0.393	0.700	0.648	0.448	0.533	0.507
O(Y/$\overline{Y}_t$)^2	**3.726**	**4.780**	**4.109**	**15.79**	**2.749**	**8.084**	**-13.04**	**2.523**	**0.001**	**0.151**	**-0.002**	**0.150**	**-0.106**	**0.709**	**-0.085**	**0.488**
prob	0.016	0.000	0.151	0.004	0.005	0.000	0.300	0.000	0.978	0.853	0.301	0.859	0.873	0.641	0.631	0.833
O(KL/$\overline{KL}_t$)	**16.65**	**8.82**	**20.87**	**39.96**	**3.99**	**24.80**	**9.23**	**3.37**	**0.00**	**-0.25**	**0.01**	**-0.24**	**0.76**	**6.31**	**0.12**	**7.14**
prob	0.000	0.000	0.000	0.000	0.004	0.000	0.735	0.003	0.950	0.866	0.158	0.876	0.493	0.009	0.663	0.055
O(KL/$\overline{KL}_t$)^2	**-1.24**	**-0.90**	**-3.44**	**-3.10**	**-0.73**	**-2.17**	**-14.42**	**-0.22**	**-0.01**	**-0.15**	**0.00**	**-0.16**	**-0.23**	**-1.09**	**-0.07**	**-1.39**
prob	0.224	0.006	0.001	0.187	0.005	0.063	0.059	0.465	0.397	0.664	0.027	0.649	0.367	0.026	0.311	0.076
O(KL/$\overline{KL}_t$)(Y/$\overline{Y}_t$)	**-6.52**	**-2.50**	**-1.83**	**-14.62**	**-0.04**	**-8.52**	**38.59**	**-1.15**	**0.03**	**0.69**	**0.01**	**0.72**	**0.48**	**-0.10**	**0.21**	**0.60**
prob	0.000	0.000	0.297	0.001	0.949	0.000	0.002	0.034	0.095	0.203	0.022	0.196	0.311	0.918	0.167	0.686

Note: The F-test that OY/$\overline{Y}_t$ = 0 and O(Y/$\overline{Y}_t$)^2= 0 is rejected at the 1% level.
O(KL/$\overline{KL}_t$) = 0 and O(KL/$\overline{KL}_t$)^2 = 0 is rejected at the 1% level.

TABLE A2: Regression Results: dependent variable = pollution intensity of IMPORTS (country fixed effects suppressed)

	VOC	PT	CO	SO2	PM10	NO2	TSS	BOD	MET air	MET land	MET water	MET total	TOX air	TOX land	TOX water	TOX total
n=	1183	1183	1183	1183	1183	1183	1183	1183	1183	1183	1183	1183	1183	1183	1183	1183
R^2 adj	0.659	0.681	0.632	0.652	0.622	0.703	0.573	0.633	0.621	0.650	0.638	0.648	0.633	0.655	0.674	0.652
constant	**3627**	**1927**	**8321**	**10176**	**1024**	**4521**	**25424**	**892**	**43**	**1163**	**5**	**1212**	**1991**	**3637**	**268**	**5862**
prob	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TIME	**-20.10**	**-11.54**	**-54.08**	**-72.54**	**-6.99**	**-31.30**	**-241.3**	**-0.73**	**-0.28**	**-6.50**	**-0.03**	**-6.81**	**-0.51**	**-11.47**	**-0.02**	**-11.95**
prob	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.080	0.000	0.000	0.000	0.000	0.359	0.000	0.907	0.000
OPEN	**0.91**	**-1.76**	**-10.82**	**-6.73**	**-2.13**	**1.06**	**-61.64**	**-1.22**	**-0.09**	**-2.47**	**-0.01**	**-2.57**	**-1.67**	**-4.27**	**-0.39**	**-6.33**
prob	0.538	0.006	0.015	0.135	0.000	0.587	0.007	0.005	0.003	0.002	0.006	0.002	0.020	0.020	0.041	0.020
OY/$\overline{Y}_t$	**-8.74**	**-1.41**	**-7.13**	**2.23**	**0.31**	**-13.31**	**44.67**	**-4.24**	**0.13**	**3.69**	**-0.01**	**3.81**	**-4.03**	**-8.12**	**-1.55**	**-13.68**
prob	0.000	0.083	0.174	0.695	0.691	0.000	0.081	0.000	0.000	0.000	0.036	0.000	0.000	0.001	0.000	0.000
O(Y/$\overline{Y}_t$)^2	**2.097**	**-0.091**	**0.087**	**-4.534**	**-0.380**	**3.031**	**-23.47**	**1.409**	**-0.054**	**-1.514**	**0.002**	**-1.566**	**1.455**	**2.461**	**0.568**	**4.474**
prob	0.022	0.784	0.964	0.039	0.174	0.011	0.010	0.000	0.000	0.000	0.163	0.000	0.000	0.007	0.000	0.001
O(KL/$\overline{KL}_t$)	**2.64**	**2.04**	**12.28**	**3.18**	**1.68**	**5.05**	**36.39**	**2.97**	**0.01**	**0.28**	**0.01**	**0.31**	**3.10**	**7.09**	**1.02**	**11.19**
prob	0.057	0.000	0.000	0.364	0.001	0.007	0.035	0.000	0.465	0.587	0.000	0.566	0.000	0.000	0.000	0.000
O(KL/$\overline{KL}_t$)^2	**-0.24**	**-0.52**	**-3.24**	**-1.84**	**-0.52**	**-0.76**	**-15.92**	**-0.39**	**-0.02**	**-0.37**	**0.00**	**-0.39**	**-0.39**	**-1.16**	**-0.12**	**-1.68**
prob	0.530	0.000	0.000	0.022	0.000	0.141	0.000	0.004	0.000	0.003	0.000	0.002	0.015	0.002	0.012	0.004
O(KL/$\overline{KL}_t$)(Y/$\overline{Y}_t$)	**-0.20**	**0.32**	**1.96**	**4.77**	**0.27**	**-0.18**	**17.21**	**-0.65**	**0.03**	**0.84**	**0.00**	**0.87**	**-0.67**	**-0.69**	**-0.27**	**-1.62**
prob	0.802	0.234	0.143	0.004	0.119	0.868	0.001	0.013	0.000	0.000	0.994	0.000	0.036	0.348	0.007	0.156

Note: The F-test that OY/$\overline{Y}_t$ = 0 and O(Y/$\overline{Y}_t$)^2= 0 is rejected at the 1% level.
O(KL/$\overline{KL}_t$) = 0 and O(KL/$\overline{KL}_t$)^2 = 0 is rejected at the 1% level.

TABLE A3: Regression Results: dependent variable = PTT (country fixed effects suppressed)

	VOC	PT	CO	SO2	PM10	NO2	TSS	BOD	MET air	MET land	MET water	MET total	TOX air	TOX land	TOX water	TOX total
n=	1181	1181	1181	1181	1181	1181	1181	1181	1181	1181	1181	1181	1181	1181	1181	1181
R^2 adj	0.884	0.882	0.881	0.866	0.812	0.898	0.871	0.883	0.867	0.867	0.879	0.867	0.832	0.845	0.842	0.840
constant	**0.929**	**0.905**	**0.908**	**0.920**	**0.840**	**0.905**	**0.771**	**1.217**	**0.908**	**0.947**	**0.921**	**0.946**	**1.038**	**1.005**	**1.117**	**1.021**
prob	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
TIME	**-0.002**	**-0.004**	**-0.002**	**-0.009**	**0.000**	**-0.002**	**0.000**	**-0.012**	**-0.007**	**-0.010**	**0.002**	**-0.010**	**-0.001**	**-0.002**	**0.002**	**-0.001**
prob	0.022	0.000	0.033	0.000	0.990	0.021	0.968	0.000	0.001	0.000	0.001	0.000	0.150	0.024	0.000	0.077
OPEN	**-0.003**	**0.000**	**0.000**	**-0.002**	**0.004**	**-0.002**	**0.002**	**-0.002**	**0.000**	**0.000**	**0.001**	**0.000**	**0.000**	**0.000**	**0.001**	**0.000**
prob	0.000	0.884	0.426	0.020	0.000	0.000	0.001	0.055	0.745	0.990	0.008	0.977	0.287	0.404	0.185	0.901
$OY/\overline{Y}_t$	**0.003**	**-0.006**	**-0.002**	**-0.003**	**-0.010**	**0.000**	**-0.005**	**-0.001**	**-0.006**	**-0.007**	**0.000**	**-0.007**	**0.002**	**0.001**	**0.004**	**0.002**
prob	0.072	0.000	0.110	0.107	0.000	0.799	0.003	0.561	0.001	0.003	0.848	0.003	0.108	0.210	0.014	0.133
$O(Y/\overline{Y}_t)^2$	**0.001**	**0.003**	**0.001**	**0.002**	**0.003**	**0.001**	**0.001**	**0.001**	**0.002**	**0.003**	**-0.001**	**0.003**	**-0.001**	**-0.001**	**-0.002**	**-0.001**
prob	0.542	0.000	0.020	0.001	0.000	0.026	0.041	0.161	0.001	0.002	0.249	0.002	0.021	0.296	0.000	0.095
$O(KL/\overline{KL}_t)$	**0.003**	**0.004**	**0.002**	**0.005**	**0.003**	**0.004**	**0.001**	**0.000**	**0.002**	**0.002**	**0.000**	**0.002**	**-0.001**	**0.000**	**-0.002**	**0.000**
prob	0.000	0.000	0.000	0.000	0.006	0.000	0.239	0.971	0.063	0.124	0.896	0.122	0.108	0.539	0.011	0.741
$O(KL/\overline{KL}_t)^2$	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**	**0.000**
prob	0.654	0.059	0.147	0.376	0.088	0.476	0.240	0.410	0.442	0.624	0.406	0.616	0.851	0.606	0.900	0.814
$O(KL/\overline{KL}_t)(Y/\overline{Y}_t)$	**-0.002**	**-0.001**	**-0.001**	**-0.002**	**0.000**	**-0.002**	**0.001**	**0.000**	**-0.001**	**-0.001**	**0.001**	**-0.001**	**0.001**	**0.000**	**0.001**	**0.000**
prob	0.003	0.000	0.003	0.000	0.395	0.000	0.284	0.435	0.238	0.220	0.062	0.225	0.019	0.840	0.002	0.241

Note: The F-test that $OY/\overline{Y}_t = 0$ and $O(Y/\overline{Y}_t)^2 = 0$ is rejected at the 1% level.
$O(KL/\overline{KL}_t) = 0$ and $O(KL/\overline{KL}_t)^2 = 0$ is rejected at the 1% level.